ENERGETICS

Ideas and information for using energy in agriculture effectively

Energy Ontario

Ontario

Published by the Ontario Ministry of Agriculture and Food Agricultural Energy Centre 801 Bay Street Toronto M7A 2B2 (416) 965-9519

AGDEX 774.42
87-4507

PERFORMANCE OF A GROUND LOOP BURIED ONE METRE DEEP

HELMUT SPIESER, P. ENG.
O.M.A.F.
RIDGETOWN, ONTARIO
NOP 2CO

DECEMBER 1986

ABSTRACT

Monitoring was carried out on a heat pump system which was coupled to a ground loop buried one metre below the soil surface. Loop entering temperatures remained within 3 to 5C° of undisturbed soil temperature at the same one metre depth.

PERFORMANCE OF A GROUND LOOP BURIED ONE METRE DEEP

BY

HELMUT SPIESER

ONTARIO MINISTRY OF AGRICULTURE AND FOOD

BACKGROUND

Earth-coupled or ground coupled heat pumps are being used more and more to provide house heating for farm homes. There are a number of reasons why this is happening. Since most of these farm homes are large and exposed to the harsh winter environment, the heating costs with conventional fossil fuels are high. Water source heat pumps can provide the required heat at a reasonable cost. Secondly, space is usually available around these homes to install a horizontal group loop.

OBJECTIVE

To determine the ground loop operating temperatures, for a loop buried one metre below the soil surface, with respect to undisturbed soil temperatures at the same depth.

NOTE: The mention of manufacturers' trade names is for the purposes of specific equipment description and does not indicate an endorsement of that equipment or discrimination of similar equipment by the author or Ontario Ministry of Agriculture and Food.

SYSTEM

Testing was carried out on a water source heat pump system which has been operating for one year, in a new farm house. The house is a brick ranch situated in a location where there is no shelter from the wind. A Cantherm Duo 520 (5 Ton) water-to-air heat pump provides the heating and cooling requirements of this home. This heat pump also supplies all the domestic hot water required by the family of six.

A horizontal ground loop coupled to the heat pump provides the heat source/heat sink for the system. This ground loop consists of 460m of 32mm inside diameter, schedule 80 polyethylene pipe. This pipe was buried, as a single pipe in a trench, one metre deep in a field adjacent to the house. Approximately half the ground loop is in saturated Berrien sandy loam.

TESTING

Thermocouples, k-type, were installed at various points of the system to monitor temperatures. A digital temperature monitor was used to measure temperatures on a twice weekly basis. The following points were monitored; loop into heat pump
loop out of heat pump
undisturbed soil at one metre depth

Electrical energy used by the heat pump and the in-plenum electric backup heater was metered by individual 100 Amp. 220V. kilowatthour meters. Domestic hot water useage was also measured with a Neptune 20mm type S positive displacement hot water meter, with a totalizer, for the twelve month monitoring period.

RESULTS

Figure 1 illustrates graphically the incoming loop temperature to the heat pump and the undisturbed soil temperature at one metre depth over time. From the graph it can be seen that the entering loop temperature follows the undisturbed soil temperature very closely. The incoming loop temperature remains approximately 3-5C°

colder than the undisturbed soil temperature, when in the heating mode. This coincides with testing carried out by Spieser 1982 where a ground loop 1.7m deep remained roughly 2C° colder than undisturbed soil at 1.7m deep, during the heating season.

The temperature relationship changed when the system switched to the cooling mode. For the first three weeks of cooling, the loop temperature was 3C° higher than the undisturbed soil. This is to be expected because heat from the loop is now being rejected to the soil. For the remainder of the cooling period, the loop temperature fluctuated less than 3C° above and below the undisturbed soil temperature.

The incoming loop temperature bottomed out at 2°C and remained very near this temperature from January through March. Starting in April the loop temperature started to raise in temperature.

Domestic hot water temperature was set at 66°C.

The total cost for heating and hot water production from October through May was $985.05. The total cost for cooling and hot water production from June through September was $222.35. The total annual cost of operation for this heat pump was approximately $1200. Calculations for cost of operation can be found in Appendix II at the end of this report.

CONCLUSIONS

1. This ground loop buried one metre deep, performs well acting as the source for the heat pump which heats the house and the domestic hot water.
2. The loop temperature remains within 3-5C° of undisturbed soil temperature at the same depth as the loop. This holds true for both the heating and cooling modes.
3. The coldest temperature reached by the incoming loop was 2°C. The coldest undisturbed soil temperature was 5°C.
4. The warmest loop temperature reached was 22°C while the warmest soil temperature was 21°C.

SUMMARY

This ground loop performs well as the heat source/heat sink for this home heating system. Over the whole year, the entering loop temperature remained within 3-5C° of undisturbed soil temperature at the same one metre depth. The fact that nearly half the loop is buried in saturated soil aids this loop in remaining above freezing through the winter months.

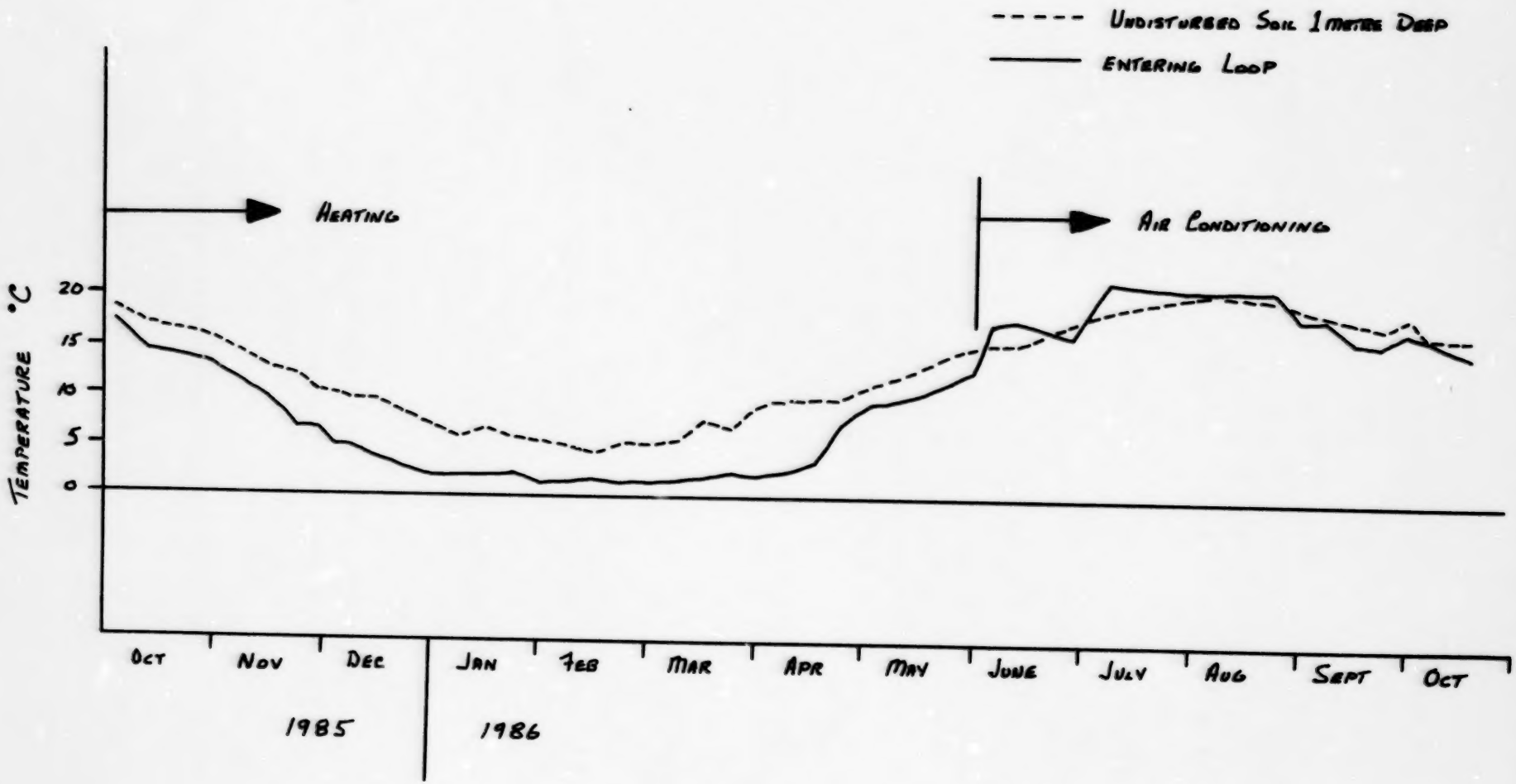
ACKNOWLEDGEMENTS

The author would like to thank the cooperator, Mr. Bill Parks, for his diligent recording of data on this project. As well, for his cooperation in allowing this monitoring to be carried out at this home. Thank you also to Ontario Hydro, Western Region, London for providing two kilowatthour meters for monitoring purposes.

REFERENCES

SPIESER, H. TESTING OF A GROUND LOOP HEAT RECOVERY SYSTEM FOR A WATER-SOURCE HEAT PUMP IN A FARM HOME - 1982

FIGURE 1 LOOP & SOIL TEMPERATURE VS TIME



APPENDIX I

HEAT PUMP PERFORMANCE

Heat pump performance tests were carried out under the following conditions:

1. The heat pump was supplying heat to the building only, no domestic hot water production. The hot water circulation pump was turned off and associated valves were closed to prevent thermosyphoning from the heat pump to the hot water storage tank.

2. The heat pump was allowed to reach steady state operating conditions before readings were taken.

Heat output was established by using measured power input, measured liquid flow through the heat pump and measured loop entering and exiting temperatures.

$$\text{HEAT OUTPUT} = \text{HEAT FLOW} + \text{POWER INPUT}$$

$$= (\dot{m}\, Cp \triangle T) + (\text{POWER INPUT})$$

$$\text{HEAT OUTPUT(MJ/h)} = [\dot{m}\, C_p \triangle T]10^{-3}\frac{\text{MJ}}{\text{kJ}} + [\text{POWER INPUT (kW)} \times 3.6\ \frac{\text{MJ}}{\text{kWh}}]$$

Where $\dot{m}$ = total measured liquid flow kg/h

Cp = specific heat of water 4.184 kJ/kg - °C

$\triangle T$ = temperature difference between loop entering and exiting the heat pump °C

HEAT OUTPUT AT VARIOUS LOOP TEMPERATURES

DATE	LOOP FLOW	LOOP TEMP. IN	LOOP TEMP. OUT	$\triangle T$	POWER INPUT	HEAT OUTPUT
Oct.2/85	.84L/s	14.4°C	10°C	4.4°C	5.76kW	76.4MJ/h
Jan.7/86	.91	1.7	-1.7	3.4	4.63	63.3
Mar.7/86	.92	0.5	-2.8	3.3	4.63	64.8
Apr.24/86	.91	5.0	2.2	2.8	5.29	57.9

NOTE: MJ/h x 9.486 x 10^2 = BTU/h

APPENDIX II

HEAT PUMP COST OF OPERATION

SYSTEM PARTICULARS:

1.) Brick ranch style house 330m^2 plus full basement.

2.) Well insulated house; Walls R-25, Ceiling R-50, Basement Walls R-15.

3.) Heat pump supplies heating and cooling needs plus all the domestic hot water needs.

4.) 15 kW in-plenum resistance backup heat.

5.) Family size; two adults plus four teenagers.

6.) Electricity costs $0.05/kWh.

7.) 5 Ton water-to-air heat pump coupled to 460m long ground loop.

ENERGY & HOT WATER USEAGE

DATE	ACCUMULATED HEAT PUMP kWh METER	ACCUMULATED IN-PLENUM HEATER kWh METER	ACCUMULATED HOT WATER USED- LITRES	
1985				
Oct. 02	610kWh	45470kWh	3200L	
Oct. 28	1694	45470	14800	
Nov. 28	3981	45480	24700	
Dec. 31	7413	46360	31700	HEATING
1986				
Jan. 31	10749	46840	42600	
Feb. 23	12866	46850	49700	
Mar. 29	15722	46850	63200	
Apr. 26	17572	46860	73700	
May 31	18921	46860	87000	
June 29	19678	46860	95000	AIR CONDITIONING
July 28	21182	46860	105800	
Aug. 30	22381	46860	115300	
Sept. 29	23368	46860	126100	

APPENDIX II - cont'd

Electricity used for heating and hot water - October to May inclusive

= 18921kWh - 610kWh = 18311kWh

Electricity for backup heat for same period

= 46860kWh - 45470kWh = 1390kWh

∴ Total electricty used for heating and hot water = 18311kWh + 1390kWh
= 19701kWh

∴ Cost for heating and hot water Oct.-May = 19701kWh x $.05/KWh
= $985.05

Electricity used for air conditioning and hot water June to Sept. inclusive

= 23368kWh - 18921kWh = 4447kWh

∴ Cost for air conditioning and hot water June-Sept. = 4447kWh x .05/kWh
= $222.35

Total annual cost of operation = $985.05 + $222.35

= $1207.40

∴ Total annual costs for heating, cooling, and all domestic hot water was approximately $1200.

APPENDIX III

HOT WATER HEATING COSTS IF HEATED WITH CONVENTIONAL ELECTRIC HOT WATER HEATER

ASSUMPTIONS:

Hot water used for 12 month period = 126100L - 3200L
= 122900L

Well water temperature 10°C

Hot water temperature 66°C

Specific heat of water Cp = 4.184kJ/kg - °C

Electricity costs $0.05/kWh

Cost to heat hot water with conventional electric heater

$$= \frac{122900L \times 1kg/L \times 4.184kJ/kg\text{-}^{\circ}C \times (66\text{-}10)C^{\circ} \times \$0.05/kWh}{3.6 \times 10^{3} kJ/kWh}$$

= $399.94

∴ To heat 122900L of hot water with conventional electric hot water heater would be approximately $400.00.